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Morphometric Similarity between the Turtles *Kinosternon subrubrum hippocrepis* and *K. baurii*

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The eastern mud turtle (*Kinosternon subrubrum subrubrum*) and the striped mud turtle (*K. baurii*) have often been reciprocally misidentified in the eastern United States. Traditionally the two taxa were differentiated on the basis of pigmentation patterns: *K. baurii* typically exhibits three longitudinal carapace stripes and a pair of well-defined stripes on either side of the head, whereas *K. s. subrubrum* lacks such discrete pigmentation (Ernst et al., 1994). Nonetheless, variable expression of striping patterns in *K. baurii* has complicated efforts to differentiate consistently the two species in areas of sympatry throughout northern Florida, Georgia, the Carolinas, and southern Virginia. A reliable alternative for identification involves the use of discriminant function analysis (DFA) to classify questionable specimens on the basis of morphological traits (Lamb, 1983; Lamb and Lovich, 1990).

In earlier surveys (Lamb, 1983; Lamb and Lovich, 1990), we noticed a striking resemblance between Mississippi mud turtles (*K. s. hippocrepis*) and *K. baurii* with respect to head striping, which is considered diagnostic for both taxa (Ernst, 1974; Iverson, 1977). Moreover, DFA of a limited number of *K. s. hippocrepis* classified them morphometrically as *K. baurii* (Iverson, pers. comm.; Lovich and Lamb, unpubl. data), an observation corroborated by Wilson (in press), who employed the discriminant functions of Lamb and Lovich (1990). Herein we provide a more detailed assessment of morphometric similarity between *K. s. hippocrepis* and *K. baurii*, as well as certain comparisons with other members of the "subrubrum" group (Iverson, 1988, 1991).

Methods.—We examined 74 adult *K. s. hippocrepis* (>70 mm plastron length and for which we had complete data) from a series of localities, mostly west of the Mississippi River (Appendix 1) and outside their reputed zone of intergradation with *K. s. subrubrum* (Iverson, 1977). Eleven shell characters were measured to the nearest 0.1 mm with digital calipers (Table 1). From these nontransformed data, discriminant scores were derived using the following sex-specific two-group discriminant functions of Lamb and Lovich (1990), which distinguish *K. baurii* from *K. s. subrubrum*:

Females

Discriminant score

$$= 0.32989(CW) - 0.18114(PL)$$
$$+ 0.05534(PA) - 0.41545(PC)$$

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TABLE 1. Summary statistics for male and female *Kinosternon s. hippocrepis* and *K. baurii* with complete data. Means (mm) are followed by standard deviations. Sample sizes are in parentheses. Abbreviations for variables defined in Lamb and Lovich (1990) are as follows: CW = carapace width, PL = plastron length, PA = plastron width at the gular-anterior humeral scutes, PC = plastron width at the posterior humeral-femoral scutes, I = intergular scute length, G = gular scute length, AH = anterior humeral scute length, PH = posterior humeral length, F = femoral scute length, A = anal scute length, and FL = plastron forelobe length. Plastron scute terminology follows Hutchison and Bramble (1981).

	Species/sex			
	K. baurii		*K. s. hippocrepis*	
Variable	♂ (54)	♀ (88)	♂ (25)	♀ (49)
CW	55.8, 5.1	62.8, 5.8	55.8, 4.7	64.5, 5.8
PL	67.3, 6.3	84.3, 7.7	66.3, 5.4	81.7, 7.9
PA	28.2, 2.9	32.5, 3.6	27.4, 3.5	31.8, 3.7
PC	32.1, 2.7	38.2, 3.4	31.0, 2.5	38.0, 3.9
I	9.0, 1.8	10.6, 2.1	8.8, 1.9	10.6, 2.4
G	13.5, 2.0	15.8, 2.6	13.9, 1.7	15.0, 3.0
AH	2.5, 1.4	2.4, 1.4	2.6, 1.0	3.3, 1.6
PH	20.8, 2.6	25.1, 3.0	19.6, 2.2	24.1, 2.8
F	4.7, 1.2	5.9, 2.0	4.0, 1.1	5.0, 1.2
A	16.9, 2.0	25.1, 2.7	17.3, 1.6	24.5, 2.5
FL	24.9, 2.3	28.6, 2.6	25.3, 2.4	28.7, 2.7

$$+ 0.21335(I) + 0.09978(G)$$
$$+ 0.11516(AH) - 0.29116(PH)$$
$$+ 0.40144(FL) - 1.33202$$

Males

Discriminant score
$$= 0.19979(CW) - 0.30907(PL)$$
$$+ 0.18596(PA) - 0.45300(PC)$$
$$+ 0.09885(I) - 0.12075(PH)$$
$$+ 0.0827(F) + 0.48112(A)$$
$$+ 0.53173(FL) - 3.47756.$$

Using the protocol of Lamb and Lovich (1990) male *Kinosternon* with scores < −0.5 are classified morphologically as *K. baurii*, as are females with scores <0.3. Mean discriminant scores for each sex were tested against these cutoff values using a one-sample t-test. In addition, we used unpublished data from our previous *Kinosternon* survey to calculate sexual dimorphism indices, which often vary among species, following the method of Lovich and Gibbons (1992). Statistical techniques follow Lamb and Lovich (1990). Means and one-sample t-tests were calculated using SYSTAT (Wilkinson, 1990) and STATGRAPHICS (STSC, 1986), respectively.

Results.—Summary statistics for the variables used in the sex specific discriminant functions are shown in Table 1. Discriminant scores for males ranged from −3.077 to 1.985 with a mean of −1.151 (Fig. 1). The
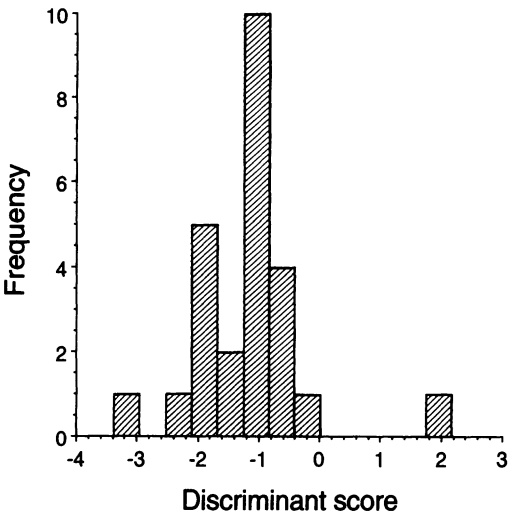

FIG. 1. Discriminant scores for male *Kinosternon subrubrum hippocrepis*.

mean discriminant score was significantly less than the cutoff value of −0.5 defining the upper limit of male *K. baurii* morphology (t = −3.51, P < 0.001). Twenty-two of 25 males (88%) had discriminant scores less than −0.5 and were classified morphologically as *K. baurii*. Discriminant scores for females ranged from −3.112 to 2.485 with a mean of −0.223 (Fig. 2). As in males, the mean discriminant score was significantly less than the cutoff value of 0.3 defining the upper limit of female *K. baurii* morphology (t = −2.71, P < 0.01). Thirty-three of 49 females (67%) had discriminant scores less than 0.3 and were classified morphologically as *K. baurii*. In addition to similar head striping patterns, three specimens of *K. s. hippocrepis* possessed faint shell stripes.

Sexual dimorphism is pronounced in *K. baurii* and *K. s. hippocrepis*, with females attaining mean carapace lengths significantly greater (>10%) than males (Table 2). In contrast, mean carapace length does not differ significantly between the sexes in *K. s. subrubrum* or *K. s. steindachneri*.

Discussion.—Previous taxonomic surveys utilizing biochemical (Seidel et al., 1986), karyological (Sites et al., 1979), and morphological data (Iverson, 1988, 1991) suggest a close phylogenetic relationship between *K. subrubrum* and *K. baurii*, although none of these studies treated *K. s. hippocrepis* as a discrete taxonomic unit in their analyses. Nonetheless, *K. s. subrubrum* and *K. baurii* are readily distinguished morphometrically by DFA (Lamb and Lovich, 1990). Employing the same discriminant functions that differentiate these two taxa, we have demonstrated remarkable morphometric similarity between *K. s. hippocrepis* and *K. baurii*. Conversely, *K. s. hippocrepis* and *K. s. subrubrum* were well-differentiated from each other. The concordant direction and magnitude of sexual dimorphism and the similarity of pigmentation patterns in *K. s. hippocrepis* and *K. baurii* provide additional, independent evidence of their overall similarity. The fact that the putative subspecies of *K. subrubrum* (*subrubrum*, *hippocrepis*, and *steindachneri*) exhibit varying degrees and directions of sexual size dimorphism is highly un-
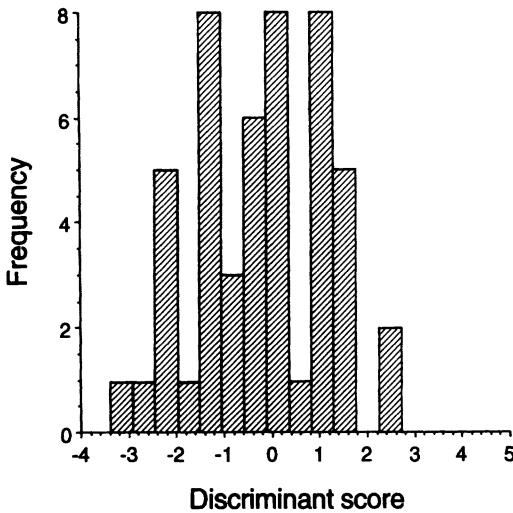
FIG. 2. Discriminant scores for female *Kinosternon subrubrum hippocrepis*.

usual. We are aware of no other turtle species in which the direction of sexual size dimorphism varies among subspecies. As a whole the Kinosternidae exhibit fairly conservative sexual size dimorphism relative to other turtle families (Gibbons and Lovich, 1990), although the degree of dimorphism can vary as a function of body size (Iverson, 1991).

We recognize that the predictive power of discriminant functions derived in our previous study (Lamb and Lovich, 1990) may be limited in their ability to classify specimens of *Kinosternon* from outside the geographic range of that survey. Specimens of *K. s. hippocrepis*, for example, were not included in the original analysis because the survey focused on *Kinosternon* from the Atlantic Coastal Plain. However, classification results of Lamb (1983) were subsequently confirmed by Lamb and Lovich (1990), indicating that the derived discriminant functions are quite robust. Discrepencies in the accuracy of classification between the sexes may be due to certain limitations posed by the function derived for females, a pattern

TABLE 2. Sexual dimorphism in *Kinosternon subrubrum* and *K. baurii*. Sexual dimorphism indices (SDI's) are calculated using the method of Lovich and Gibbons (1992). Taxa in which mean carapace lengths of males and females are significantly different (ANOVA, $P < 0.05$) are marked with an asterisk. Sample sizes are in parentheses and incorporate specimens not included in Table 1.

| Taxon | Mean carapace length (mm) | | SDI |
	♂	♀	
K. s. subrubrum	87.9 (100)	89.8 (106)	0.02
K. s. steindachneri	99.1 (23)	95.4 (22)	−0.04
K. s. hippocrepis*	80.1 (25)	89.6 (61)	0.12
K. baurii*	83.2 (66)	92.1 (119)	0.11

observed by Lamb (1983). Nonetheless, it is important to underscore the fact that the mean discriminant scores for both sexes of *K. s. hippocrepis* were significantly less than the cutoff values defining the upper limit of *K. baurii* morphology.

These results prompt a controversial question: Is *K. s. hippocrepis* more closely allied evolutionarily to *K. baurii* than it is to *K. s. subrubrum*? Although the reported morphometric similarities between *K. s. hippocrepis* and *K. baurii* are striking, we emphasize the fact that our data are purely phenetic. However, our survey does call to question the long accepted subspecific composition of *K. subrubrum*, reputedly comprising *subrubrum*, *steindachneri*, and *hippocrepis*. A detailed cladistic analysis, one encompassing range-wide surveys of *K. subrubrum* and *K. baurii* and employing both genetic and morphological characters, will be required to determine whether the observed similarities between *K. baurii* and *K. s. hippocrepis* reflect phylogenetic affinity or a remarkable case of convergence.

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APPENDIX 1

Specimens Examined

Museum acronyms follow Leviton et al. (1985). ARKANSAS. Ashley Co.: USNM 48190. Poinsett Co.: USNM 99835–38. LOUISIANA. USNM 64615, 64619. Assumption Parish: UF 54695. Calcasieu Parish: UF 12015, 32627, 34114. Cameron Parish: UF 34113, 34115, JBI571, JBI577. East Carrol Parish: UF JBI581. Jefferson Davis Parish: USNM 100099, 100101. Livingston Parish: USNM 100178, 100185, 100188, 100195. Natchitoches Parish: USNM 100581, 100583–4. Orleans Parish: AMNH 4525–8, 4532, 4535. UF 2173.2, 30393, 30395. USNM 13233, 13237–40, 13242–4, 13246–7, 19941–3, 21372, 21374, 21376–8, 55637, 65906. Plaquemines Parish: USNM 238636. Sabine Parish: UF JBI569. St. Mary Parish: USNM 68055. St. Charles Parish: UF 14644. Vermillion Parish: AMNH 64016. UF 61918, JBI573. USNM 210114. TEXAS. UF 40431, Austin Co.: UF 751. Dallas Co.: USNM 95387. Harrison Co.: AMNH 16986. Hopkins Co.: UF 30442. Jasper Co.: UF 12016-2. Jefferson Co.: UF JBI570. Matagorda Co.: USNM 246924. McClennan Co.: USNM 55635–6. Van Zandt Co.: USNM 83694, 83696.

An Anomalous Specimen Referable to Rhadinaea kinkelini (Serpentes: Colubridae), from Chiapas, Mexico

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During an investigation of the taxonomic status of several species of Rhadinaea from Chiapas, Mexico, and Guatemala, we examined a specimen obtained by T. J. Pappenfuss at Lago Montebello, Chiapas, Mexico, on 17 August 1976 (California Academy of Sciences [CAS] 142629). Lago Montebello is one of several lakes in the Parque Nacional de las Lagunas de Montebello; this park lies near the Guatemalan border in the eastern highlands of Chiapas, Mexico. The specimen is similar to Rhadinaea kinkelini Boettger, a species not reported from Mexico (McCranie and Wilson, 1991; Flores-Villela, 1993). After comparison with material in the University of Kansas collection and the detailed descriptions provided by Myers (1974), we concluded that this specimen possesses most of the diagnostic characteristics of R. kinkelini, except that it has 19-19-19 dorsal scale rows (DSR) rather than 17-17-17, as in all known specimens of R. kinkelini (Myers, 1974; McCranie and Wilson, 1991). Dorsal scale row counts have been used as diagnostic characters in the classification of Rhadinaea (Myers, 1974), although they do vary occasionally (Myers, 1974; Mendelson and Kizirian, 1995).

In the case of CAS 142629, we have two taxonomic options: (1) consider it as either an anomalous or a geographic variant of R. kinkelini and add this species to the herpetofauna of Mexico, or (2) describe a new species based on this unique specimen that may be diagnosed from R. kinkelini by having 19, rather than 17, DSR. We argue that the former option is more tenable until additional material becomes available primarily because of the fact that DSR do vary, albeit with low frequency, among some species of Rhadinaea, including members of the Rhadinaea godmani group (sensu Myers, 1974).

The specimen from Mexico (CAS 142629) is an adult male (hemipenis everted) with the following characteristics: snout–vent length 190 mm, tail (incomplete) 57 mm, DSR 19-19-19, ventrals 144, subcaudals 53+, subpreocular absent, postoculars 2, supralabials 8, infralabials 8, and temporals 1 + 2. The color pattern (Fig. 1) is typical of R. kinkelini (Myers, 1974; McCranie and Wilson, 1991), but CAS 142629 has an additional pair of thin, dark paravertebral lines (adjacent portions of DSR 6–7 and 7–8).

Rhadinaea kinkelini is known from only few localities in Nicaragua, Honduras, El Salvador, and Guatemala (McCranie and Wilson, 1991). In Guatemala, R. kinkelini is known only from the Highlands of Alta Verapaz and the Sierra de las Minas (Myers, 1974; Campbell and Vannini, 1989). These two areas share many species of reptiles and indeed are most similar to one another faunally (Campbell and Vannini, 1989). These areas share few species with the Southeastern Highlands, although Campbell and Vannini (1989) stated that R. kinkelini probably does occur there; this supposition is likely based on records from Hacienda Monte Cristo (KU 63886–87; Myers, 1974), in adjacent El Salvador.

It is noteworthy that R. kinkelini has not been found in the Sierra de los Cuchumatanes of Guatemala. This massive range is contiguous with the Lagunas de Montebello region of Chiapas, whence CAS 142629 was taken. Furthermore, the humid areas of the Sierra de los Cuchumatanes are separated from similar habitat in the Alta Verapaz and Sierra de las Minas region by the low and xeric valley of the Río Negro. The resultant faunal disjunction is evident in that the Sierra de los Cuchumatanes possesses the most distinctive herpetofaunal assemblage in Guatemala (Stuart, 1943; Campbell and Vannini, 1989). Nevertheless, it is possible that R. kinkelini does occur in the Sierra de los Cuchumatanes, but has not yet been discovered